Chapter 5: Chemical changes 1

Knowledge organiser

Reactions of metals

The **reactivity** of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have *high* reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have *low* reactivity.

Reactivity series

The reactivity series places metals in order of their reactivity.

Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are non-metals.

Reaction with water	Reaction with acid	Reactivity series: Metal	Reactivity series: Reactivity	Extraction method
fizzes, gives off hydrogen gas	explodes	potassium	high reactivity	electrolysis
	fizzes, gives off hydrogen gas	sodium		
		lithium		
		calcium		
		magnesium		
		aluminium		
reacts very slowly		(carbon)		
		zinc		reduction with carbon
		iron		
no reaction	reacts slowly with warm acid	tin		
		lead		
		(hydrogen)		
	no reaction	copper		
		silver		mined from the Earth's crust
		gold	low reactivity	

Decreasing reactivity

Metal extraction

Some metals, like gold, are so unreactive that they are found as pure metals in the Earth's crust and can be mined.

Most metals exist as compounds in rock and have to be extracted from the rock. If there is enough metal compound in the rock to be worth extracting it is called an **ore**.

Metals that are less reactive than carbon can be extracted by reduction with carbon. For example:

iron oxide + carbon → iron + carbon dioxide

Metals that are more reactive than carbon can be extracted using a process called **electrolysis**.

Reduction and oxidation

If a substance gains oxygen in a reaction, it has been **oxidised**.

If a substance loses oxygen in a reaction, it has been **reduced**.

For example:

iron + oxygen → iron oxide

iron has been oxidised

iron oxide + carbon → iron + carbon dioxide

iron oxide has been reduced

Salts

When acids react with metals or metal compounds, they form salts. A salt is a compound where the hydrogen from an acid has been replaced by a metal. For example nitric acid, HNO_3, reacts with sodium to form $NaNO_3$. The H in nitric acid is replaced with Na.

The table shows how to name salts.

Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula	HCl	H_2SO_4	HNO_3
Ions formed in solution	H^+ and Cl^-	$2H^+$ and SO_4^{2-}	H^+ and NO_3^-
Type of salt formed	metal chloride	metal sulfate	metal nitrate
Sodium salt example	sodium chloride, NaCl	sodium sulfate, Na_2SO_4	sodium nitrate, $NaNO_3$

Displacement reactions

In a **displacement** reaction a *more* reactive element takes the place of a *less* reactive element in a compound.

For example:

copper sulfate + iron → iron sulfate + copper

$CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s)$

Iron is more reactive than copper, so iron displaces the copper in copper sulfate.

Reactivity and ions

A metal's reactivity depends on how readily it forms an **ion** by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with iron ions, not copper ions.

Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example, $CuSO_4(aq)$ can be written as $Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$.

The displacement reaction of copper sulfate and iron can be written as:

$$Fe(s) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Fe^{2+}(aq) + SO_4^{2-}(aq) + Cu(s)$$

The SO_4^{2-} is unchanged in the reaction – it is a **spectator ion**. Spectator ions are removed from the equation to give an **ionic equation**:

$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$

Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

Steps for writing an ionic equation (HT only)

1. check symbol equation is balanced
2. identify all aqueous ionic compounds
3. write those compounds out as ions
4. remove spectator ions.

Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$$

A copper ion gains two electrons to form a copper atom:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

These two equations are called **half equations** – they each show half of the ionic equation.

Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the loss or gain of electrons.

Oxidation is the *loss* of electrons, and reduction is the *gain* of electrons.

In the example displacement reaction:

- iron atoms have been oxidised
- copper ions have been reduced.

Acids and alkalis

Acids are compounds that, when dissolved in water, release H^+ ions. There are three main acids: sulfuric acid H_2SO_4, nitric acid HNO_3, and hydrochloric acid HCl.

Alkalis are compounds that, when dissolved in water, release OH^- ions.

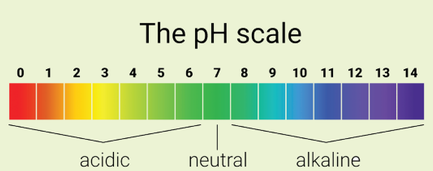
The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

- Aqueous solutions with pH < 7 are acidic.
- Aqueous solutions with pH > 7 are alkaline.
- Aqueous solutions with pH = 7 are neutral.

Indicators

Indicators can show if something is an acid or an alkali.

- **Universal indicator** can also tell us the approximate pH of a solution.
- Electronic pH probes can give us the exact pH of a solution.



Chapter 5: Chemical changes 2

Knowledge organiser

Reactions of acids

Reactions of acids with metals

Acids react with some metals to form salts and hydrogen gas.

magnesium + hydrochloric acid → sodium chloride + hydrogen

Neutralisation reactions

Reactions of acids with metal hydroxides

Acids react with metal hydroxides to form salts and water.

hydrochloric acid + sodium hydroxide → sodium chloride + water

The ionic equation for this reaction is always:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Reactions of acids with metal oxides

Acids react with metal oxides to form salts and water.

hydrochloric acid + sodium oxide → sodium chloride + water

Reactions of acids with metal carbonates

Acids react with metal carbonates to form a salt, water, and carbon dioxide.

hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide

Alkalis and bases

Bases neutralise acids to form water in **neutralisation** reactions. Some metal hydroxides dissolve in water to form alkaline solutions, called alkalis.

Some metal oxides and metal hydroxide do not dissolve in water. They are **bases**, but are not alkalis.

Strong and weak acids

Sulfuric acid, nitric acid, and hydrochloric acid, are all **strong acids**. This means that, when dissolved in water, every molecule splits up into ions – they are completely ionised:

- $H_2SO_4(aq) \rightarrow 2H^+(aq) + SO_4^{2-}(aq)$
- $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$
- $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

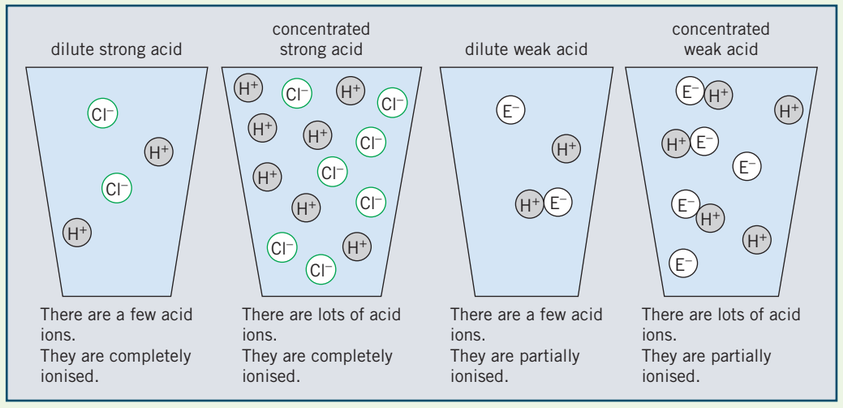
Ethanoic acid, citric acid, and carbonic acid are **weak acids**. This means that only a percentage of their molecules split up into ions when dissolved in water – they are partially ionised.

For a given concentration, the *stronger* the acid, the *lower* the pH.

Concentrated and dilute acids

Concentration tells us how much of a substance there is dissolved in water:

- more concentrated acids have lots of acid in a small volume of water
- less concentrated acids (dilute acids) have little acid in a large volume of water.



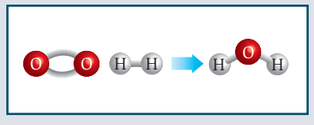
Balancing symbol equations

When writing symbol equations you need to ensure that the number of each atom on each side is equal.

$H_2 + O_2 \rightarrow H_2O$

unbalanced

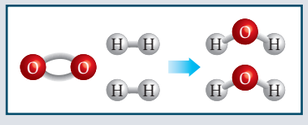
there are 2 hydrogen atoms on each side, but 2 oxygen atoms in the reactants and 1 in the product



$2H_2 + O_2 \rightarrow 2H_2O$

balanced

there are 4 hydrogen atoms on each side, and 2 oxygen atoms on each side



State symbols

A balanced symbol equation should also include state symbols.

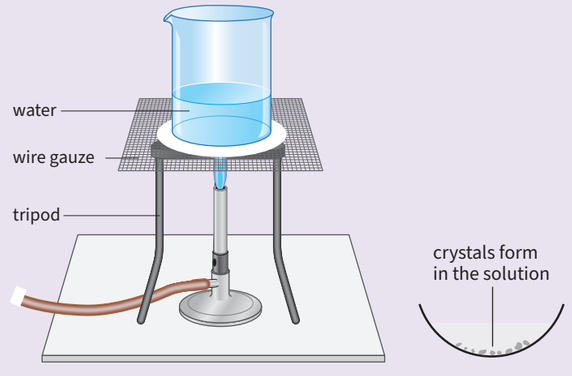
State	Symbol
solid	(s)
liquid	(l)
gas	(g)
aqueous or dissolved in water	(aq)

Crystallisation

You can produce a solid salt from an insoluble base by **crystallisation**.

The experimental method is:

1. Choose the correct acid and base to produce the salt.
2. Put some of the dilute acid into a flask. Heat gently with a Bunsen burner.
3. Add a small amount of the base and stir.
4. Keep adding the base until no more reacts – the base is now in excess.
5. Filter to remove the unreacted base.
6. Add the remaining solution to an evaporating dish.
7. Use a water bath or electric heater to evaporate the water. The salt crystals will be left behind.



Key terms

Make sure you can write a definition for these key terms.

displacement, electrolysis, extraction, half equation, ion, ionic equation, metal, ore, oxidation, reactivity, reactivity series, redox, reduction, spectator ion, state symbols